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PRUNE AND CHERRY BROWN-ROT INVESTIGATIONS IN THE PACIFIC NORTHWEST.

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CONTENTS.

INTRODUCTION.

The present bulletin reports the results of five years' investigation of prune and cherry brown-rot in the lower Columbia and Willamette Valleys of Washington and Oregon. The climatic conditions of the section are less favorable to the development of brown-rot than those of the Eastern States, but more favorable than on the eastern slope of the Cascades or in the Rocky Mountain region. The average annual rainfall is about 45 inches (weather records for Portland, Oreg.), but more than 35 inches of this falls in the six months beginning with October and ending with March, about 5 inches during

April and May, and less than 5 inches in the four months beginning with June and ending with September. The average monthly rainfall for July and August is less than three-fourths of an inch. Showery weather often prevails during the blooming season for prunes and cherries, but this is soon followed by relatively dry weather that usually continues through the cherry-picking period and sometimes well into the prune harvest. The weather conditions are thus rather unfavorable for the development of brown-rot, but they are not extreme enough to eliminate the disease. In most years brown-rot attracts but little attention, but occasionally it breaks into a serious epidemic that causes the loss of a large percentage of the crop. The destructive phases of the disease have taken two forms—one an infection of the blossoms and the other a rotting of the fruit as it approaches maturity.

BLOSSOM INFECTION.

Blossom infection usually makes its first appearance as a browning or blackening of the under calyx lobes where drops of water have hung. In some cases it spreads down the pedicel, the fruit often turning back on its stem, while in others it confines itself largely to the petals and calyx, causing the young fruit to separate readily from its stem. The browned and blackened parts usually persist for a considerable time, furnishing a ready means of distinguishing the diseased blossoms from those that are yellowing from starvation or a lack of pollination. (Pl. I, figs. 1, 2, 4–6; Pl. II, *A*.)

During the five years from 1915 to 1919, inclusive, when orchards were under close observation by the writers, blossom infection always occurred on both prunes and cherries. In each of these years counts of the infected and healthy blossoms were made on representative trees. The results are shown in Table 1. It will be seen that in some years the prune orchards were practically free from blossom infection, while in others from one-third to one-half of the young prunes were destroyed by brown-rot. The infection on the sweet cherries was even more serious than on the prunes. This subject will be given further consideration under headings relating to plowing, cultivation, and spraying.

TABLE 1.—*Count of blossoms infected with brown-rot on representative prune and cherry trees.*

Year.	Variety and location.	Percentage affected.	Year.	Variety and location.	Percentage affected.
1915	Italian Prune, Felida, Wash.	40	1916	Black Republican cherry, Salem, Oreg.	26
1916	do	Trace.[1]		Napoleon cherry, Salem, Oreg.	4
1917	do	35	1917	Black Republican cherry, Salem, Oreg.	65
	Italian Prune, Springbrook, Oreg.	64		Napoleon cherry, Salem, Oreg.	51
	Italian Prune, Dundee, Oreg.	52	1918	Black Republican cherry, Salem, Oreg.	17
1918	Italian Prune, Felida, Wash.	Trace.[1]		Napoleon cherry, Salem, Oreg.	32
1919	Italian Prune, Salem, Oreg.	12	1919	do	86
1915	Black Republican cherry, Salem, Oreg.	85			

[1] Less than 1 per cent.

APOTHECIA.

Two methods of overwintering are known for the brown-rot fungus, one by means of twig cankers and the mummied fruit on the trees and the other by the rotten and mummied fruit on the ground. Careful observation indicated that under conditions in the Northwest the fallen fruit and resulting apothecia are largely responsible for carrying the disease through the winter.

Apothecia were abundant under the prune trees in unplowed orchards and were found in considerable number on the mummied cherries. So far as the writers have been able to learn this is the first instance in which cherry apothecia have been reported. (Pl. I, fig. 3, and Pl. III, fig. 2.)

The prunes and cherries that were partly buried in the trash or soil appeared to be most favorably situated for the development of apothecia, but prunes that were buried to a depth of 2 or 3 inches also fruited rather freely, and in some instances apothecia were traced to prunes that were buried to the extreme depth of 5 inches.

TIME RELATION OF APOTHECIA, BLOSSOMS, AND BLOSSOM INFECTION.

The weather conditions favorable for bringing the trees into bloom are also favorable in general for the development of apothecia. Table 2 gives the results of observations on this point.

TABLE 2.—*Apothecial, blooming, and infection dates in prune orchards at Salem, Oreg., in 1919, and at Felida, Wash., in the 4-year period, 1915–1918.*

Year.	First apothecia.	Maximum number of apothecia.	First blossoms open.	First infection.	Serious infection.
1915	Apr. 2	Apr. 8	Mar. 24	Apr. 5	Apr. 8
1916	Apr. 1	Apr. 7	Apr. 8	.....	.....
1917	Apr. 18	Apr. 30	Apr. 27	May 9	May 18
1918	Apr. 6	Apr. 16	Apr. 11	.....	.....
1919	Apr. 1	Apr. 9	Apr. 7	.....	Apr. 16

It was observed that under favorable conditions a period of eight days elapsed between the time the prune apothecia broke through the soil and the shedding of the first spores and that they continued to shed spores for at least a week.

In both the prune and the cherry orchards the apothecia were usually shedding their spores by the time the blossoms were open, and they continued to do so throughout the blooming period. Full chance was thus given for the start of the disease on the blossoms, the extent of the infection varying with the prevalence of damp and showery weather.

RELATION OF PLOWING, CULTIVATION, AND CHARACTER OF SOIL.

In observations in various orchards during the five years' study it was found that those not plowed or cultivated until after the blossoming season (as is frequently the case) usually had an abundance

of apothecia, while those that had been plowed and cultivated before this time were practically free from them except in tree rows or other unplowed areas. Apothecial clusters were sometimes found at the rate of three or more to the square foot in the uncultivated tree-row spaces and yet were entirely absent in the cultivated portions of the orchard.

Fruit that is plowed under and deeply buried is not likely to produce apothecia, and plowing or deep harrowing in the early spring and during blossoming is likely to disturb the partly formed apothecia and prevent further development.

Different soils are not equally favorable to the development of apothecia. They were found in greater abundance on the moist bottom lands than on the well-drained hills. They seemed to be almost entirely absent on the coarse " red-shot " clay soils.

Orchards that were free from apothecia through cultivation or otherwise were found to be practically free from blossom infection and usually relatively free from brown-rot.

FRUIT INFECTION.

After the blossom stage was passed practically no brown-rot was found on the prunes and cherries till they approached maturity. The green fruit is usually relatively resistant to disease, and the low midsummer rainfall was unfavorable for infection. As the harvest season approached, brown-rot again became evident, but during the five years when the disease was under special observation there was never a severe epidemic of brown-rot in the orchard, the larger part of the losses sustained occurring on the harvested fruit while in transit or while at the drier or the cannery. In some years, however, the spread of the disease in the orchard has caused severe losses. It was estimated by the growers that the epidemic in the fall of 1923 resulted in the rotting of about one-third of the prune crop while still on the trees. (Pls. IV and V.)

SPRAYING EXPERIMENTS ON PRUNES.

Spraying experiments were made in the Italian Prune orchards of A. W. Moody, of Felida, Wash., during the four years, 1915–1918, and in the Italian and Agen (*Petite*) Prune orchard of L. T. Reynolds, at Salem, Oreg., in 1916 and 1919. The work was done with gasoline power sprayers, and special attention was given to securing a fine, well-distributed spray.

SPRAYING EXPERIMENTS IN 1915.

The experiments in 1915 were started with the standard spraying materials, 4–4–50 Bordeaux mixture, 8–8–50 self-boiled lime-sulphur, and commercial lime-sulphur 1 to 50 and 1½ to 50. As the season advanced it was found that these materials did not spread and stick well on the fruit, and modifications were made to meet these conditions. Two pounds of rosin-fishoil soap were added to each 50 gallons of Bordeaux mixture or self-boiled lime-sulphur, and in the second orchard 2 gallons of flour paste (containing 2 pounds of

flour) were added to each 50 gallons of diluted commercial lime-sulphur. The soap was found very efficient as a spreader and sticker, but the paste was less satisfactory.

Sprayings were made in the first orchard on March 17, when the buds were showing white; on March 24, when the blossoms were ready to open (Pl. III, fig. 1); on April 8, after the blossoms had fallen; on May 1, when the husks were shed; on June 21; and on August 6, when the fruit was beginning to color. In the second orchard, sprayings were made on March 17, May 29, June 21, and August 6.

On April 5 blossom infection was becoming prevalent and by April 8 had become serious. Notes were taken May 10 to 15 to determine the effect of the spraying in saving the set of fruit. Counts of the number of fruit spurs that had borne blossoms and the number of prunes still remaining were made on representative branches from the different plats. The first spraying on these plats was made with Bordeaux mixture and the second and third with self-boiled lime-sulphur. The results are shown in Table 3.

TABLE 3.—*Effect of early spraying upon the set of prunes.*

Sprayings applied.	Prunes set per 4,000 spurs.	Sprayings applied.	Prunes set per 4,000 spurs.
First, second, and third	292	First and third	143
First and second	243	None	69
Second	369	.....do	86

The results show that the sprayed trees had retained from two to five times as much of their fruit as the unsprayed. This difference in set was somewhat evened up by a later drop, but records taken at harvest time showed that the average yield on plats that had received either the second or third spraying was more than double that of the plats on which both these sprayings were omitted.

Early in August spray injury became evident on the foliage of the lime-sulphur plats. The injury was as bad where the commercial solution had been diluted 1 to 50 as where diluted 1½ to 50. It was estimated that about 15 per cent of the leaves were affected and that the total leaf area had been reduced about 10 per cent. Lime-sulphur also appeared to increase the fruit drop. The Bordeaux mixture and self-boiled lime-sulphur plats were free from injury.

Frequent showers occurred during the last three weeks of May, but the weather during the latter part of the summer was comparatively dry. The occurrence of brown-rot was noted on some of the plats in the latter part of May, but there was no serious outbreak at any time during the summer.

The prunes were harvested September 7 to 10. A count was made of the entire crop from the five trees of each plat. A crate of sound fruit was packed from each plat, shipped to Wenatchee, Wash., by ordinary express, and held without refrigeration till September 21

to determine the effect of the spraying upon the holding or carrying quality of the fruit. The results are shown in Figure 1 and in Plate II, *B*.

The amount of brown-rot at harvest time was not large on any of the plats, but was greater on the unsprayed plats than on the sprayed. The contrast between the sprayed and unsprayed prunes in the holding test is very striking and shows the value of spraying as a means of removing the sources of infection and also as a preventive of losses in case of shipment or in delay in harvesting or drying. The relatively small amount of brown-rot on the unsprayed trees was apparently due in large measure to the reduction in sources of infection accomplished by spraying the remainder of the orchard, for in neighboring unsprayed orchards more than three-fourths of the crop was affected with brown-rot at harvest time, and the harvested

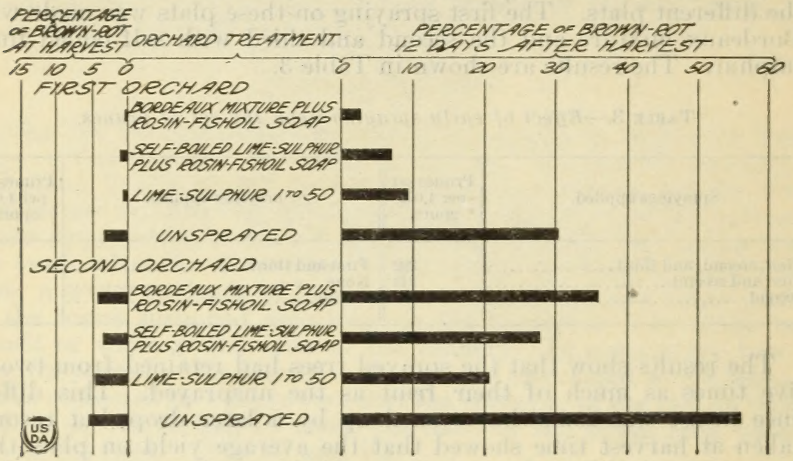


FIG. 1.—The effect of spraying upon the development of brown-rot on Italian Prunes in the orchard and after harvest; experiments of 1915. The trees of the first orchard were 24 years old and those of the second were 15.

fruit was scarcely in a usable condition if allowed to stand over night at the drier.

SPRAYING EXPERIMENTS IN 1916.

In the 1916 experiments the same sprays were used as in 1915, and in addition to the spraying program plats at Felida, Wash., were treated with 50–50 sulphur-dust mixture (50 pounds of sulphur dust and 50 pounds of hydrated lime). In the second and third applications 10 pounds of the hydrated lime in the dust mixture were replaced by powdered arsenate of lead for the control of the syneta leaf-beetle, and 1 pound of arsenate of lead powder was also added to each 50 gallons of spray material. Applications were made in the orchard at Felida on April 8 to 12, April 25 to 27, May 30, and August 30, and in the orchard at Salem, Oreg., on April 1, April 21, and June 16. The first application was made just before blooming in each case, the second just after the blossoms had fallen, the third when the husks had been shed, and the fourth as the fruit

was beginning to color. There was very little blossom infection in either orchard. Lime-sulphur again caused some injury to the foliage, but not quite as much as in the previous year. It was also found that the addition of 4 pounds of lime to each 50 gallons of lime-sulphur resulted in materially reducing the foliage injury.

The prunes from the Felida orchard were harvested on September 12 and 23. Fruit from the first picking was shipped in pony refrigerators to Washington, D. C., received in good condition on September 19, and held at a temperature of 70° to 80° F. till September 23, when notes were taken. There was practically no rot on the prunes in the Salem orchard. They were harvested September 6; sound fruit was shipped by ordinary express to Wenatchee, Wash.,

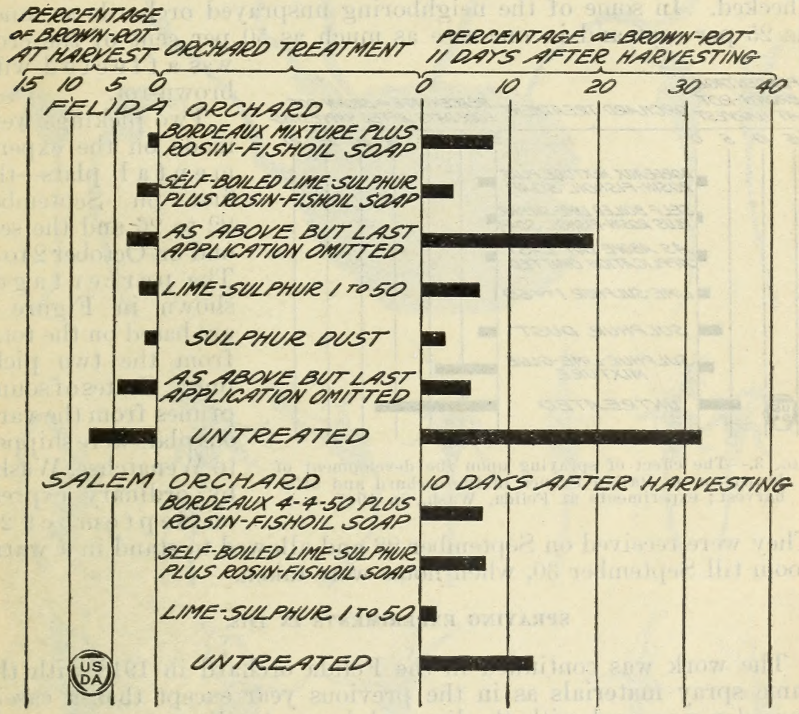


FIG. 2.—The effect of spraying upon the development of brown-rot on Italian Prunes in the orchard and after harvest; experiments of 1916.

and held at room temperatures till September 16, when the notes shown in Figure 2 were taken.

The results again emphasize the great value of spraying in improving the holding and shipping quality of the fruit even when the orchards are practically free from the disease.

SPRAYING EXPERIMENTS IN 1917.

The spraying experiments were continued in the Felida orchard in 1917. The spray mixtures were the same as those used in the 1916 experiments except that an additional plat was treated with a

sulphur-lime-glue mixture (8 pounds of superfine sulphur, 8 pounds of hydrated lime, and 3 ounces of glue mixed to a paste and diluted to 50 gallons). Applications were made on April 28, May 18, June 15, and September 12, the first application being just before the blossoms opened, the second when the blossoms were off, the third when the husks were shed, and the fourth about two weeks before harvest. The season was dry, and there was practically no blossom infection in the orchard in which the experiments were made; it was quite prevalent, however, in the neighboring orchards that remained unsprayed.

The weather was showery for several days at the beginning of prune harvest, and brown-rot began to develop on the unsprayed plat. Dry weather followed, and the spread of the disease was checked. In some of the neighboring unsprayed orchards as much as 25 per cent and in one case as much as 50 per cent of the crop was affected with brown-rot.

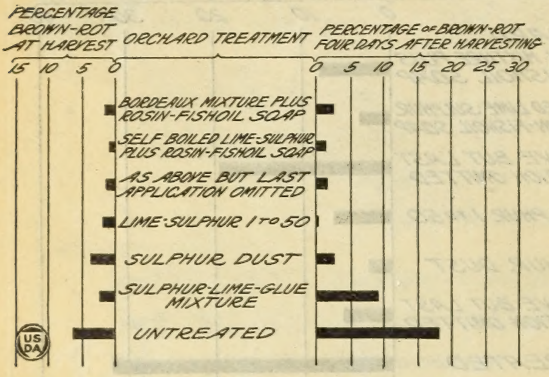


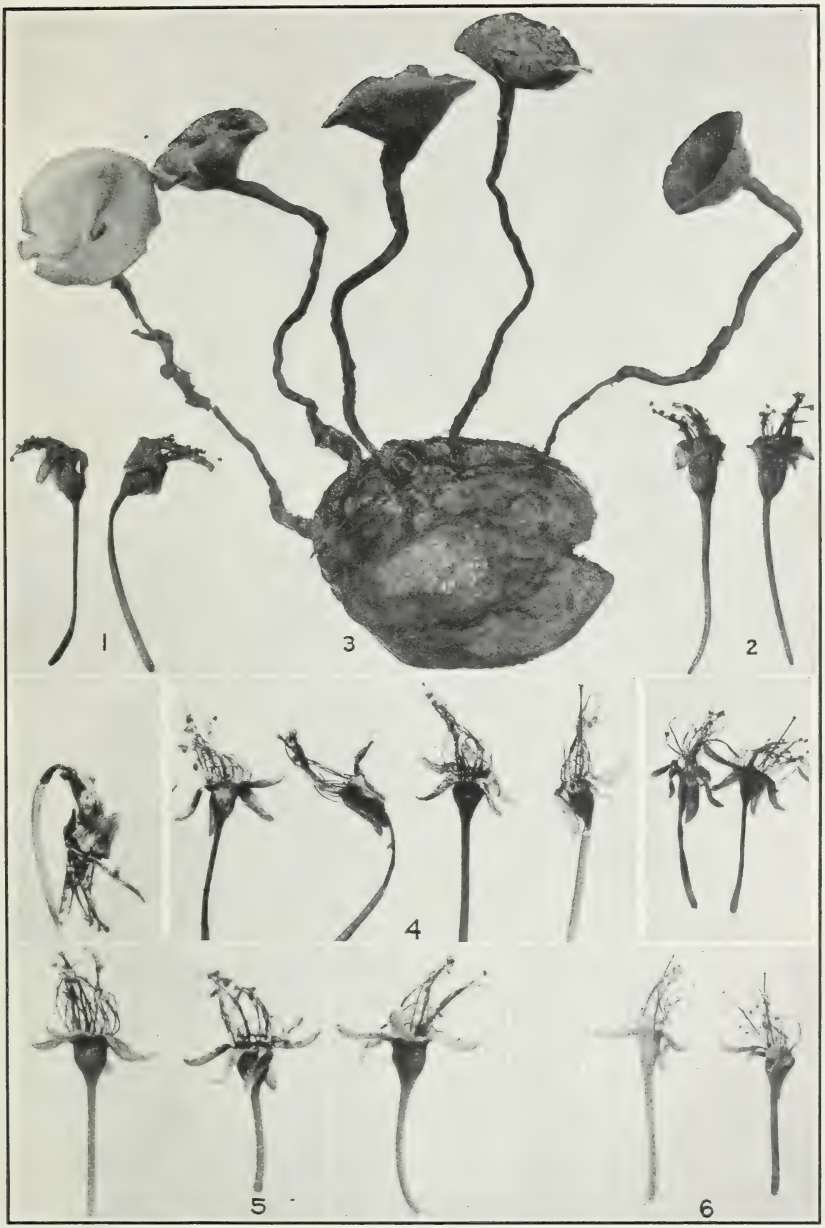
FIG. 3.—The effect of spraying upon the development of brown-rot on Italian Prunes in the orchard and after harvest; experiments at Felida, Wash., in 1917.

Two pickings were made on the experimental plats—the first on September 22 to 26 and the second on October 2 to 5. The percentages shown in Figure 3 are based on the total from the two pickings. Crates of sound prunes from the various plats were shipped to Wenatchee, Wash., by ordinary express on September 26. They were received on September 28 and allowed to stand in a warm room till September 30, when notes were taken.

SPRAYING EXPERIMENTS IN 1918.

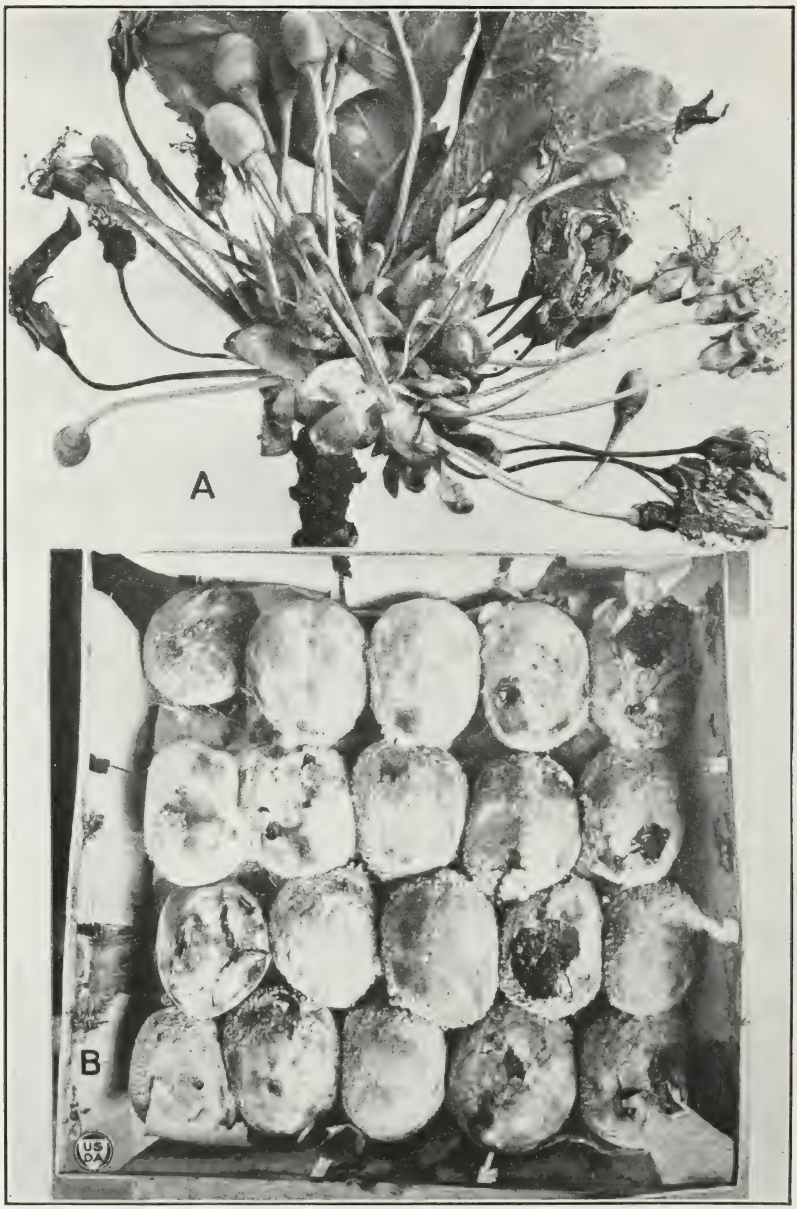
The work was continued in the Felida orchard in 1918 with the same spray materials as in the previous year except that a casein spreader was used with the lime-sulphur. Applications were made April 11, April 29, May 27, and August 20. There was little blossom infection in the orchard under treatment. The second application of Bordeaux mixture injured 5 to 10 per cent of the leaves, and the last application of lime-sulphur again caused severe injury to the foliage. On September 5 it was estimated that 10 per cent of the leaves were injured on the lime-sulphur plat, and on September 24 (after most of the fruit was harvested) fully half of the leaves were yellow and many of them had dropped to the ground.

Six different pickings were made, beginning August 31 and ending October 15, but most of the crop was harvested on September 6 and 11. There was no significant contrast in the brown-rot on the different pickings, and the results for the season are combined in



CHERRIES AND PRUNES AFFECTED WITH BROWN-ROT.

FIG. 1.—Black Republican cherries affected with brown-rot, collected at Salem, Oreg., April 13, 1915. FIG. 2.—Same as Figure 1, but not affected with brown-rot. FIG. 3.—Italian Prune mummy bearing five apothecia, collected at Felida, Wash., April 9, 1915. This prune was buried to a depth of about 2 inches, and the apothecial cups were borne just above the surface of the soil. FIG. 4.—Italian Prunes affected with brown-rot, collected at Felida, Wash., April 9, 1915. FIG. 5.—Same as Figure 4, but not affected with brown-rot. FIG. 6.—Same as Figure 5, but these are blossoms that were yellow and apparently unpollinated. Note the small size of the ovaries in comparison with those of Figures 4 and 5. All the photographs reproduced above were taken from specimens that had been preserved in formalin.



RESULTS OF CHERRY AND PRUNE INFECTION.

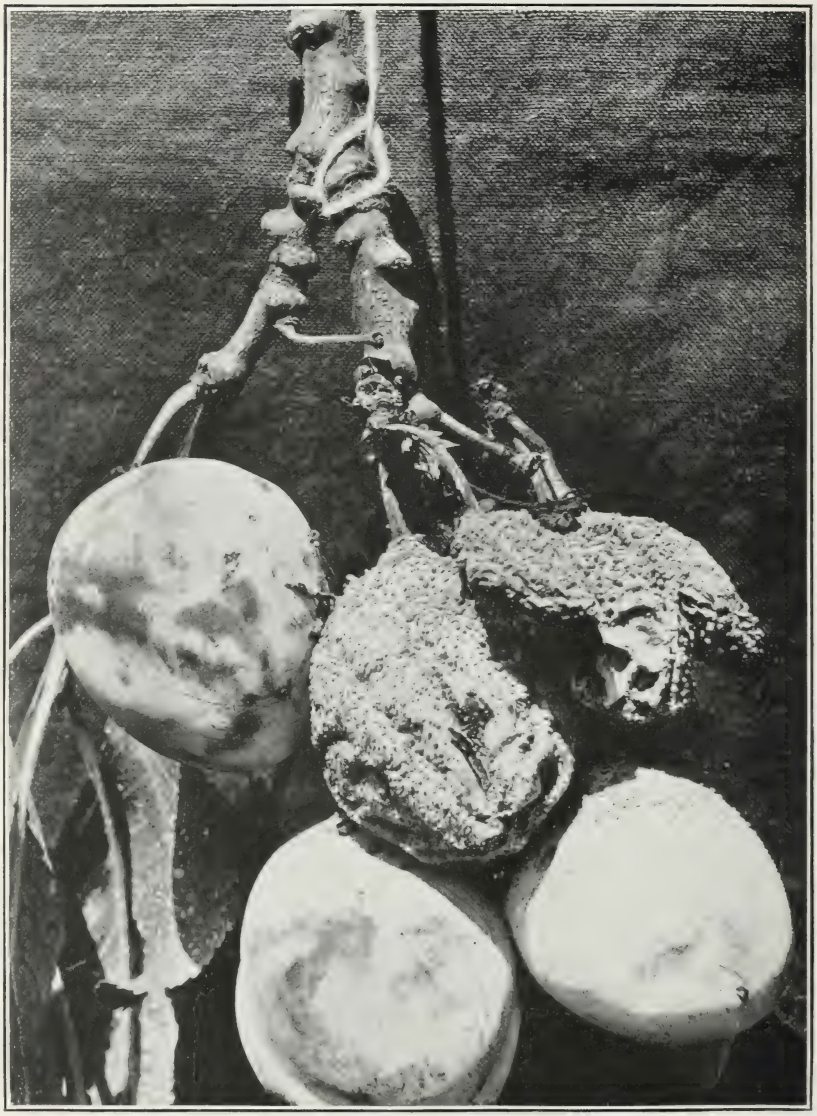
A, Brown-rot infection on young Napoleon cherries from Felida, Wash., in 1916. *B*, View of carrier of unsprayed Italian Prunes 12 days after picking. (September 21, 1915.)

FIG. 1.—ITALIAN PRUNE BLOSSOM CLUSTER.

The stage of blooming when the first spraying should be made is here shown.

FIG. 2.—BLACK REPUBLICAN CHERRY MUMMY AND ATTACHED APOTHECIA.

From the orchard of L. T. Reynolds, Salem, Oreg , March 31, 1916.



ITALIAN PRUNES AFFECTED WITH BROWN-ROT.

Photographed when the fruit was beginning to color, August 11, 1915.

IMMATURE ROYAL ANN CHERRIES AFFECTED WITH BROWN-ROT.

Photographed May 25, 1915.

the data included in Table 4. Crates of sound prunes from the various plats were shipped to Wenatchee, Wash., by ordinary express on September 11. They were received September 12, and were held in cellar storage at a temperature of approximately 59° F. till September 20, when notes were taken, as shown in Table 4. Little brown-rot was present even on the unsprayed fruit.

TABLE 4.—*Effect of spraying on the development of Italian Prune brown-rot in the orchard and after harvest at Felida, Wash., in 1918.*

Orchard treatment.	Percentage of rot on sprayed and unsprayed prunes.	
	At time of harvest.	Nine days after harvest.
Bordeaux mixture plus rosin-fishoil soap	0.3	1.3
Self-boiled lime-sulphur plus rosin-fishoil soap	.2	0
As above, but last application omitted	.2	.6
Lime-sulphur 1 to 50 plus casein	.5	0
As above, but last application omitted	.6	.3
Sulphur dust	.1	.4
Sulphur-lime-glue mixture	1.0	2.0
Untreated	.2	2.6

SPRAYING EXPERIMENTS IN 1919.

The work in 1919 was carried out in the Italian Prune and Agen (*Petite*) Prune orchards of L. T. Reynolds, at Salem, Oreg. The spray materials were the same as used in 1918 except that the lime-sulphur was diluted 1½ to 50 instead of 1 to 50, the sulphur-lime-glue mixture was omitted, and three dust plats were added, one being treated with a sulphur dust containing 85 per cent of sulphur and two with Bordeaux dust. Applications were made on April 8, April 25, May 21, and August 25, accompanying the same phenological conditions as in previous years.

The weather was showery in April, and considerable blossom infection developed. The Agen orchard had a heavier infection than the Italian. On April 16 a count was made of 10,000 blossoms on the sprayed Agen trees and of a like number on the unsprayed, and it was found that with the sprayed trees 5.1 per cent of the blossoms were infected and with the unsprayed ones 11.8 per cent.

The lime-sulphur plats again showed some foliage injury. It was estimated on May 9 that 15 per cent of the leaves were affected and on September 17 that 25 per cent showed more or less injury. On the latter date about 25 per cent of the foliage on the Bordeaux plat also showed injury, doubtless due to a period of rainy weather covering six days of the previous week. No injury appeared on the Bordeaux plat until after the rain.

The prunes were harvested September 15, and crates of sound prunes from the various plats were saved for a shipping test, as shown in Figures 4 and 5.

The results again showed the great value of spraying and dusting in improving the shipping and holding quality of the fruit. A study of Figures 4 and 5 shows that when held after harvest the fruit from

the unsprayed trees developed six to nine times as much rot as that from the trees receiving the best orchard treatment.

SUMMARY OF SPRAYING EXPERIMENTS ON PRUNES.

During the five years covered by the spraying experiments there was never a really serious outbreak of brown-rot on the fruit, yet

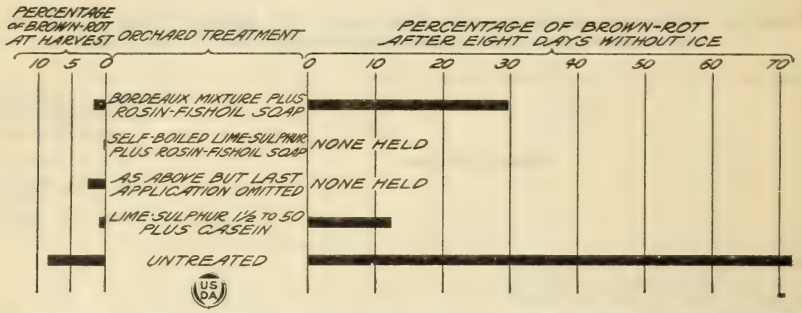


FIG. 4.—The effect of spraying upon the development of brown-rot on Italian Prunes in the orchard and after harvest; experiments at Salem, Oreg., in 1919. The bars on the right show the results from a shipment without ice which was received in Wenatchee, Wash., September 18, and held in cellar storage till September 23.

there was always considerable loss from the disease, especially in the orchards receiving the least care. The fruit from the unsprayed plats of the experimental orchards never had as much as

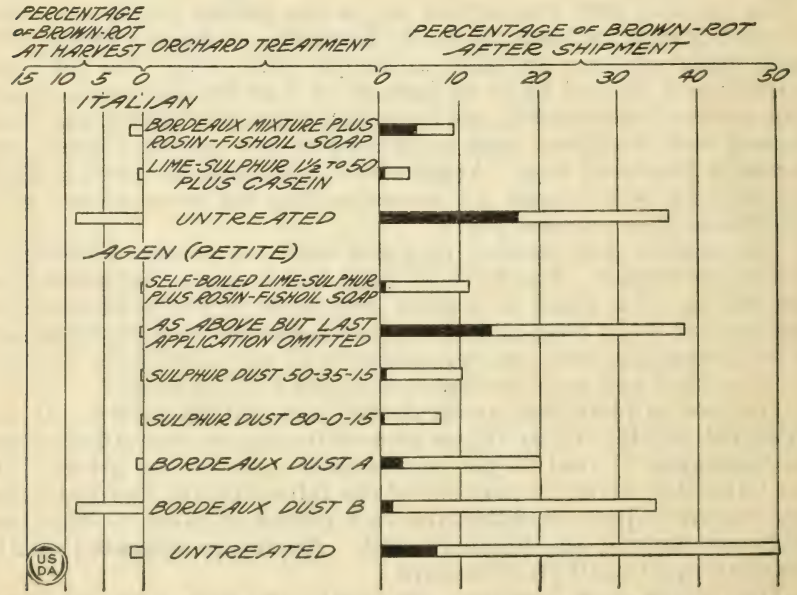


FIG. 5.—Italian and Agen (*Petite*) Prune experiments at Salem, Oreg., in 1919. The shaded bars at the right show the result of a shipment to Wenatchee, Wash., in a pony refrigerator, the fruit being held in the refrigerator under ice till September 23. The total length of the bars shows the total rot after the cool storage had been followed by two days of warm storage.

10 per cent of rot at harvest time, but a comparison of the brown-rot on the sprayed fruit with that on the unsprayed shows that the spray applications were very efficient in holding the disease in check.

A summary of the results of the five years' test on this point is brought out in Figure 6. It will be seen that the sprayed fruit had only about one-third as much brown-rot at harvest time as the unsprayed and that it developed about one-fourth as much as the unsprayed in shipping and holding tests.

The application a few weeks before picking time has been particularly important in the control of brown-rot. This fact is brought out in Figure 7, which gives a summary covering this phase of the spraying results. It will be seen that approximately half the brown-rot control was due to this late application.

Sulphur dust has given approximately as good brown-rot control as the standard spray materials. A summary of spraying and dusting results is shown in Figure 8.

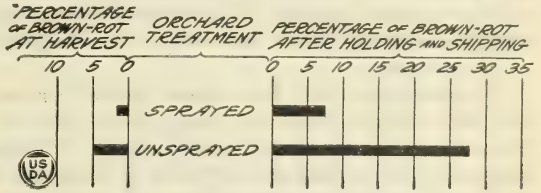


FIG. 6.—Comparison of the average development of brown-rot on sprayed and unsprayed Italian Prunes in 11 different spraying and holding experiments.

RECOMMENDATIONS FOR THE CONTROL OF BROWN-ROT OF PRUNES.

The prune brown-rot problem in the lower Columbia and Willamette Valleys is apparently not so much a matter of finding remedies as a question of how much money and effort the grower is justified in spending and is willing to spend on a disease that is more or less erratic in its occurrence. The experiments reported here seem to leave no doubt that the remedial measures that have become fairly well established in sections of the eastern United States where brown-rot is more constant in its occurrence would fully meet the situation in the humid sections of the Pacific Northwest if consistently applied.

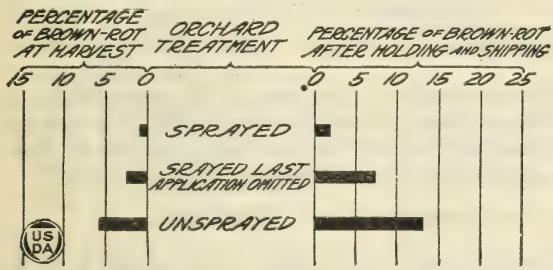


FIG. 7.—Control of brown-rot on prunes as influenced by an application of spray or dust three to five weeks before picking time. Average results from 7 orchard experiments and 11 holding tests.

The question is really one of balancing the cost of insurance against the possibility of loss and determining the most economical procedure.

Giving more careful attention to cultivation can be safely recommended as a good investment. Plowing done in the fall, winter, or early spring and frequent harrowing before and during the blooming season will decrease the number of apothecia.

Many of the orchards of this section need heavier pruning. A proper thinning and cutting back of the top encourages a renewal of fruiting wood, gives a better set of fruit, and helps to prevent brown-rot by admitting the sunlight and by giving an opportunity for thorough spraying.

An application of dust or spray three to five weeks before harvest time can be recommended as an insurance fully justified by average conditions. The advisability of spray applications just before the blossoms open, just after the petals have fallen, and just after the husks are shed may vary with the orchard and the season, but the applications are timely in all cases where brown-rot is likely to become a menace.

The effectiveness of any spray material depends very largely on the thoroughness of the application, the fineness of the spray, and the manner in which it covers and adheres. The smooth waxy skin of the prune renders it practically impossible to cover effectively and protect the fruit with any liquid material without the addition of a spreader.

Various spreaders have been tested for use on prunes, and of these the rosin-fishoil soap and casein have proved most satisfactory. The rosin-fishoil soap causes considerable foaming in the tank, hence is somewhat objectionable, while it likewise is more troublesome to prepare and more expensive than the casein. For methods of preparing spreaders, see pages 19–20.

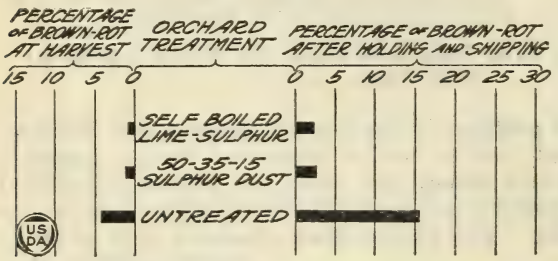


FIG. 8.—Comparative results from spraying and dusting in a 4-year test on prunes.

Both lime-sulphur and Bordeaux mixture caused more or less spray injury, particularly the former. The Bordeaux injury was always associated with rainy weather following the spraying, while the lime-sulphur injury was associated with hot weather. Because of the possibility of serious spray injury, lime-sulphur is not recommended for use on prunes, and self-boiled lime-sulphur 8–8–50 is to be preferred to Bordeaux mixture. For the method of preparing sprays, see page 17.

SPRAYING EXPERIMENTS ON CHERRIES.

The cherry-spraying experiments were made in the orchards of L. T. Reynolds, at Salem, Oreg., on the Napoleon (*Royal Ann*), Black Republican, and Lambert, all sweet varieties. Various standard spray materials were used on the different orchard plats, including 2–4–50 Bordeaux mixture plus 2 pounds of rosin-fishoil soap, 8–8–50 self-boiled lime-sulphur plus 2 pounds of rosin-fishoil soap, and commercial lime-sulphur diluted 1 to 50.

SPRAYING EXPERIMENTS IN 1915.

In 1915, spray applications were made on May 7 and 8 and June 1. None of the spray materials caused injury. There was practically no brown-rot evident at picking time. The Napoleon cherries were picked June 17 and the Black Republican June 24. Ten-pound boxes of cherries from the various plats were saved for shipping and holding tests, as shown in Figure 9.

SPRAYING EXPERIMENTS IN 1916.

The experiments were continued in 1916 in the same orchards with the same spray materials. Sprayings were made on April 1, before the blossoms had opened, on April 21, after the blossoms had fallen, on May 12, and on June 15. About 25 per cent of the blossoms on the unsprayed trees became infected with the brown-rot fungus, and about 10 per cent of those on the sprayed trees were similarly infected. None of the spray materials caused distinct injury, but the cherries from the self-boiled lime-sulphur plat were smaller than the average and in some cases somewhat shriveled. The weather was showery during the picking season of the Napoleon variety, and the fruit cracked badly, but this trouble was greatly reduced on cherries that had received sprays containing soap. It was estimated that

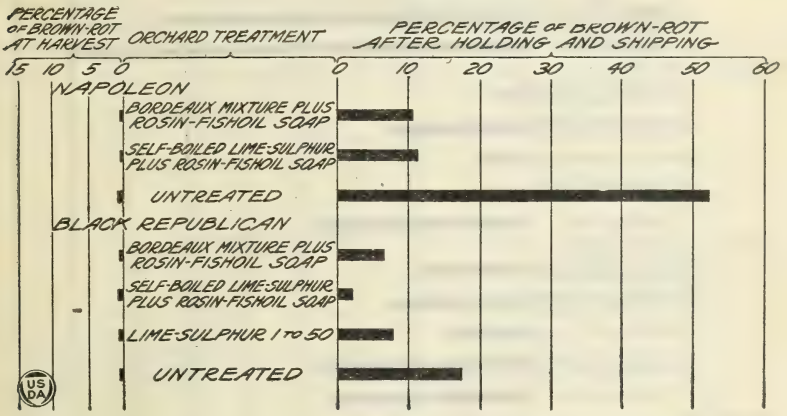


FIG. 9.—Development of brown-rot on sprayed and unsprayed cherries at harvest time and after holding; experiments of 1915. The results on Napoleon cherries as shown by the bars at the right were from fruit picked on June 17, stored at 41° F. on June 18, removed and shipped by express without refrigeration on June 27, received at Wenatchee, Wash., on June 29, and held in a warm laboratory till July 2. The results on Black Republican cherries were from fruit that was picked on June 24, stored at 41° F. on June 25, removed and shipped by express without refrigeration on June 27, received at Wenatchee, Wash., on June 29, and held in a warm laboratory till July 6.

where soap was used not more than 25 to 30 per cent of the crop was injured, while on other trees fully 75 per cent of the fruit was affected. There was practically no brown-rot on the cherries at picking time. A 10-pound box from each plat was held for observation. The Napoleon cherries were picked July 3 and 5, the Black Republican July 6 to 10, and the Lambert July 14. The results of the shipping tests are shown in Figure 10.

Considering the fact that scarcely any brown-rot could be found in the orchard, the contrast between the sprayed and the unsprayed fruit in the shipping tests is surprisingly great.

SPRAYING EXPERIMENTS IN 1917.

The experiments were continued in 1917, as in previous years. Sprayings were made on April 25, May 14, May 31, and June 22. On May 14 there was a serious blossom infection on the Napoleon and Black Republican cherries, and it was evident that the unsprayed

fruit was much more affected than the sprayed fruit. On June 21 brown-rot had become quite prevalent on the young cherries, and a count was made of sound and infected fruit from the different Black Republican plats. The results showed that 16 per cent of the fruit was affected on the self-boiled lime-sulphur plat, 11 per cent on the lime-sulphur plat, and 35 per cent on the unsprayed plat. On July 15 a count was made to determine the relation of the number of cherries to the number of fruit scars or original blossom clusters. It was found

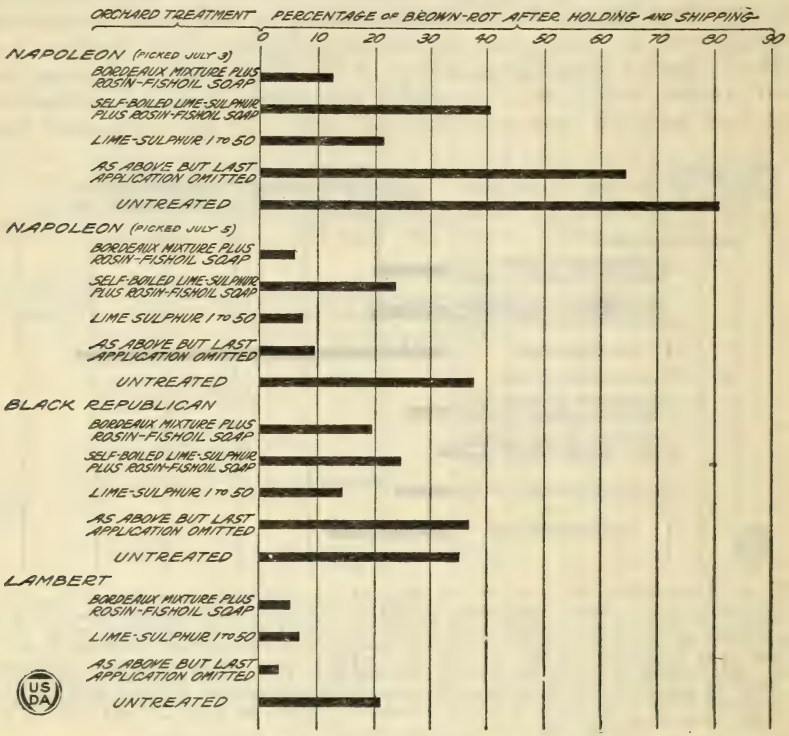


FIG. 10.—Development of brown-rot on sprayed and unsprayed cherries after holding; experiments of 1916. The first shipping test on Napoleon cherries was with fruit picked on July 3, stored at 41° F. on July 4, removed and shipped by ordinary express on July 6, received at Wenatchee, Wash., on July 8, and held in a warm laboratory until July 20. The second shipping test was with fruit picked on July 5, shipped in pony refrigerators the same day, received in Washington, D. C., on July 12 with ice pans empty and fruit warm, and held without cooling until July 13. The shipping test on Black Republican cherries was with fruit that was picked July 6 to 10, stored at a temperature of 41° F. till July 14, shipped by express without refrigeration to Wenatchee, Wash., received on July 16, and held in a warm laboratory till July 21. The shipping test with Lambert cherries was with fruit picked on July 14, shipped in pony refrigerators the same day, received in Washington, D. C., on July 21, and held till July 22.

that the set was but very slightly greater on the sprayed plats than on the unsprayed, the differences produced by blossom infection having apparently been evened up by a "drop" that occurred during the latter part of June.

On May 31 decided foliage injury was evident on the lime-sulphur plats. As the season advanced it also became evident that the cherries from the Bordeaux mixture and the self-boiled lime-sulphur plats were smaller than those that were not sprayed and that the Napoleon cherries from these plats were more highly colored than those from

the unsprayed plat. The dwarfing effect was so serious on the Black Republican fruit that the cherries from the Bordeaux mixture and the self-boiled lime-sulphur plats were discounted in price at the cannery, and some of the trees sprayed with Bordeaux mixture were not picked.

The weather was dry during the picking season, and there was practically no brown-rot in the orchard. Holding and shipping tests were made, as in the previous years.

The Napoleon cherries were picked July 7, shipped in pony refrigerators the same day, received in Wenatchee, Wash., July 12, and held in a warm room till July 14, when notes were taken.

The Black Republican cherries were picked July 15, packed in pony refrigerators the same day, and shipped to Wenatchee, Wash., where they were received July 18, held under ice till July 19, and then at room temperature till July 24, when notes were taken.

The Lambert cherries were picked July 21, shipped in pony refrigerators the same day, and received in Washington, D. C., on July 30, when notes were taken. The results are shown in Table 5.

TABLE 5.—*Development of brown-rot on sprayed cherries and unsprayed cherries, in 1917.*

Orchard treatment.	Percentage of brown-rot after holding.		
	Napoleon.	Black Republican.	Lambert.
Bordeaux plus rosin-fishoil soap	0	0.2	0.1
Self-boiled lime-sulphur plus rosin-fishoil soap	.1	0	0
As above, but last application omitted	.3	0	.....
Lime-sulphur 1-50 plus casein	0	.1	.6
Untreated	.3	2.7	5.0

SPRAYING EXPERIMENTS IN 1918.

The experiments in 1918 were confined to the Napoleon variety. The spray materials were the same as in previous years except that a neutral Bordeaux mixture (2 pounds of copper sulphate neutralized with limewater and diluted to 50 gallons) was substituted for the standard mixture and the self-boiled lime-sulphur plat was omitted in an effort to eliminate the dwarfing effects of strongly alkaline sprays on the fruit. Applications were made on April 15, May 2, May 15, and June 18.

Blossom infection was evident early in May, and counts were made at various times to determine the percentage of infection on the different plats. The results are shown in Table 6.

TABLE 6.—*Brown-rot blossom infection of Napoleon cherries in 1918.*

Orchard treatment.	Percentage of blossoms infected on—		
	May 9.	May 13.	May 17.
Bordeaux mixture	20.3	8.0	6.8
Lime-sulphur	13.4	10.0	5.9
Unsprayed	33.7	32.5	26.5

The results of the various counts show that the sprayings caused a significant reduction in the blossom infection.

Slight foliage burning was evident on the lime-sulphur plat by the middle of April, and the cherries from the Bordeaux plat were probably a little smaller than those from the unsprayed trees, but the injury of any kind resulting from spraying was very slight.

There was again practically no brown-rot in the orchard, and no counts were made at picking time. The cherries were picked on June 26, and the fruit picked in the morning was held separate from that picked in the middle of the day. The results of a shipping test are shown in Figure 11. The cherries picked in the cool of the morning developed less rot than those picked in the middle of the day, and the sprayed and dusted cherries had very much less than the untreated fruit.

SPRAYING EXPERIMENTS IN 1919.

The experiments in 1919 were continued in the same Napoleon orchard. The spray materials used were lime-sulphur 1 to 50 plus a casein spreader, a neutral Bordeaux mixture (4 pounds of bluestone to 50 gallons, neutralized with limewater) plus rosin-fishoil soap and 85–15 sulphur dust (85 per cent sulphur and 15 per cent arsenate of lead). The applications were made on June 7 and 16.

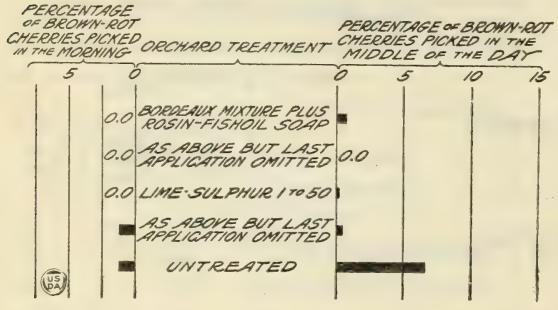


FIG. 11.—Development of brown-rot on sprayed and unsprayed cherries; experiments of 1918. The cherries were picked on June 26, shipped in pony refrigerators to Wenatchee, Wash., held under ice till July 2, and without ice one day, the notes being taken on July 3.

The cherries from the dusted and untreated plats were larger and had a better appearance than those from the sprayed plats. No distinct spray injury developed before picking time, but on September 16 a severe defoliation and yellowing affecting all the leaves was observed on the Bordeaux plat. Six days of rain had preceded, ending on September 10, and this was the first heavy rain after the spray application of June 18. It is noteworthy that such severe burning could be produced three months after the application. Practically no brown-rot developed in the orchard. The Bordeaux and lime-sulphur plats were picked June 25; showers followed, and the dusted and untreated plats were picked June 27. The first picking was held without cooling till June 27, when the shipping test shown in Figure 12 was started. The dust does not appear to have been as efficient as the sprays, but the fact that the picking was interrupted by showers may have modified the results.

SUMMARY OF SPRAYING EXPERIMENTS ON CHERRIES.

The 5-year test has indicated that sweet cherries in the lower Willamette Valley are rather susceptible to spray injury. Lime-sulphur has sometimes injured the foliage, and Bordeaux mixture

and self-boiled lime-sulphur have usually had a more or less dwarfing effect upon the fruit.

During the five years that the tests were continued there was practically no brown-rot evident in the orchards at picking time, and any conclusions as to the merits of spraying must be based on the holding quality of the fruit. A summary of the results from 18 different holding tests carried out during the five years is given in Figure 13. A study of the data shows that the sprayed cherries developed less than a third as much brown-rot as the unsprayed fruit.

The last spray application was the most important in so far as the development of brown-rot on the harvested fruit is concerned. A summary of the tests on this point is shown in Figure 14.

RECOMMENDATIONS FOR THE CONTROL OF BROWN-ROT OF CHERRIES.

The five-year investigation has not furnished a basis for definite recommendations in regard to the control of brown-rot of cherries as its occurs in the lower Willamette Valley. Fall or winter plowing and early spring harrowing both in the cherry orchards and in adjacent prune orchards would undoubtedly be of value in reducing the amount of disease occurring on the blossoms. Spraying and dusting have greatly reduced the amount of brown-rot that developed after picking, but with the small percentages of rot that have occurred at picking time and the prevailing custom of disposing of all the sweet cherries at the cannery it is a question whether systematic spraying would be profitable. If brown-rot becomes a serious menace, dusting should be given further tests in comparison with spraying.

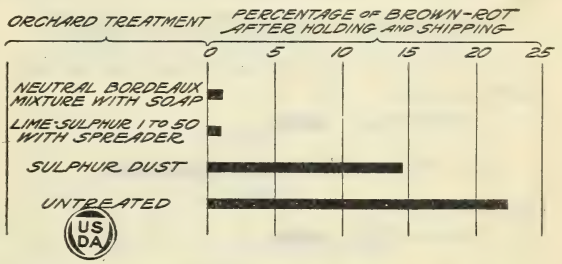


FIG. 12.—Development of brown-rot on sprayed and unsprayed cherries; experiments of 1919. The cherries were shipped from Salem, Oreg., in pony refrigerators on June 27, were received warm in Washington, D. C., on July 2, and were held at a temperature of approximately 45° F. till July 3.

PREPARATION OF SPRAYS.

SELF-BOILED LIME-SULPHUR.

The standard self-boiled lime-sulphur mixture is composed of 8 pounds of fresh stone lime and 8 pounds of sulphur to 50 gallons of water. Any finely powdered sulphur (flowers, flour, or "commercial ground" sulphur) may be used in the preparation of the mixture.

In order to secure the best action from the lime, the mixture should be prepared in rather large quantities, at least enough for 200 gallons of spray, using 32 pounds of lime and 32 pounds of sulphur. The lime should be placed in a barrel and enough water (about 6 gallons) poured on almost to cover it. As soon as the slaking of the lime is well started the sulphur should be added, after first running it

through a sieve to break up the lumps and mixing to a slush with a little water. The mixture should be stirred at intervals and more water (3 or 4 gallons) added as needed to form a moderately thick paste. It is then covered and allowed to stand four to five minutes. If on slightly stirring it is found to be growing thinner and softer and the light sulphur yellow changing to a brownish color, the process is finished, and cold water should be gradually stirred in.

If at the end of four or five minutes the mass has not softened or darkened distinctly on testing with the paddle it should be immediately covered and allowed to stand for another period of four or five minutes. This may be repeated until the above change has occurred and then the action checked by the addition of cold water. The mixture is then ready to be strained into the spray tank, diluted, and applied. If the mixture is allowed to remain hot for 15 or 20 minutes after the slaking is completed a part of the sulphur will probably have gone into solution, combining with the lime to form sulphids. The resulting spray may be injurious to peach foliage, but has greater fungicidal value and is preferred for use on prunes. The stage at which cold water should be added to stop the cooking varies with different limes. Some limes are so sluggish in slaking that it is difficult to obtain enough heat from them to cook the mixture at all, while other limes become intensely hot on slaking, and care must be taken not to allow the boiling to proceed too far. After using self-boiled lime-sulphur it is important to wash the spray tank and pump thoroughly to remove sediment.

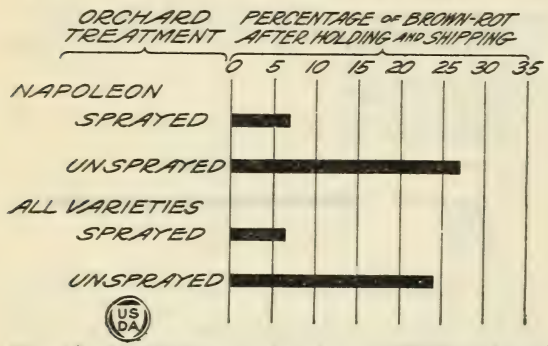


FIG. 13.—Comparison of the average development of brown-rot on sprayed and unsprayed cherries in 18 different holding and shipping tests.

BORDEAUX MIXTURE.

Bordeaux mixture is made of copper sulphate (bluestone), lime, and water. As ordinarily used on prunes for the control of brown-rot it consists of 4 pounds of copper sulphate, 4 pounds of stone lime, and 50 gallons of water. To prepare the spray it is most convenient to make stock solutions of copper sulphate and lime. A stock solution of copper sulphate is made by dissolving it at the rate of 1 pound to 1 gallon of water. It is convenient to make up stock solutions in 50-gallon lots, 50 pounds of copper sulphate being placed in a clean gunny sack and suspended just beneath the surface of an equal number of gallons of water in a barrel (one with wooden hoops being preferable). This will dissolve in 24 hours, or sooner if hot water is used. A gallon of this stock solution then contains 1 pound of copper sulphate.[1] The lime is prepared by slaking

[1] Always stir the stock solution before dipping any out.

a definite quantity of stone lime (it should be at least 90 per cent pure) in a measured quantity of water. A smoother paste and a better spray mixture will be obtained if the slaking is begun with hot water, and this is often necessary where the poorer grades of lime are used. If hot water is employed there is also less danger of drowning the lime. If cold water is used the action should be started by adding only enough water to cover the lime. As the lime begins to slake it takes up water, and more must be added, it being stirred until a paste is formed, when the remaining quantity of water may be added.

If 50 pounds of lime is used it is convenient to dilute this to 50 gallons with water to make the stock solution, 1 gallon of which is then equal to 1 pound of lime. After preparation the barrels should be covered if the material is not to be used at once, in order to prevent evaporation.

One point to be kept in mind in preparing Bordeaux mixture is that strong stock solutions should never be mixed together. The required amount of either stock solution may be added to the spray tank, a quantity of water run in, the agitator started, and the other stock solution then added. If the strong copper-sulphate stock solution is added first, it is possible to remove the coarse particles of lime from the stock solution of this material by washing it through the sieve while filling the tank. The spray tank and pump should be thoroughly washed with clean water after Bordeaux mixture has been used.

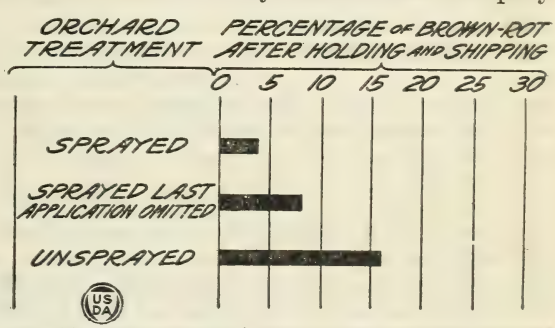


FIG. 14.—Development of brown-rot on harvested cherries as influenced by a late spray application (about three weeks before picking time).

LIME-SULPHUR SOLUTION.

Commercial preparations of lime-sulphur solution are usually readily obtainable on the market and have largely superseded the homemade product The commercial material is reasonable in price as a rule, more uniform in strength than the homemade, and spraying operations are simplified by its use, since all that is necessary to prepare the spray is to dilute the commercial concentrate with the required quantity of water.

ROSIN-FISHOIL SOAP.

Rosin-fishoil soap may be made up as follows:

Rosin	5 pounds.
Potash lye, such as is sold for washing purposes	1 pound.
Fishoil	1 pint.
Water	5 gallons.

The rosin is dissolved in the oil by heating in a large kettle. After this has partially cooled, the potash is added, the mixture being slowly stirred and carefully watched to prevent its boiling over.

A part of the water is now added and the boiling continued until the mixture will dissolve in cold water. This will require about an hour. The remainder of the water is then added slowly and the mixture thoroughly stirred. For use add 1 quart to 200 gallons of spray.

CASEIN.

Commercial caseinate spreaders may be obtained on the market, or an equally satisfactory product may be prepared at home. To prepare a casein spreader, proceed as follows:

Casein	1 pound.
Baking soda	3 ounces.
Water	1 gallon.

Mix the ingredients thoroughly and let stand for at least an hour before using. For use add 1 quart of the casein solution to 200 gallons of spray.

If the casein is of coarse granular consistency the above method will not be satisfactory, and caustic soda (ordinary lye) should be substituted for the baking soda and added to the water first. This soda solution should then be heated to the boiling point and the casein slowly added while stirring carefully to prevent the formation of lumps. The resulting solution should be diluted for use, as directed above. These liquid casein preparations do not keep well and consequently should not be made up in greater quantity than is required for a particular application.

SPRAYING SCHEDULE.

In order that the grower may have before him in a concise form the recommendations for spraying prunes and cherries offered in this bulletin, a condensed spraying schedule is given in Table 7. The first column of this table shows the character of the application and the time of applying it, stated in terms of the condition of the trees. The second column specifies the most satisfactory spray material for use on prunes, together with the proper strength to be used. The third column in similar manner specifies the most satisfactory spray material for sweet cherries.

TABLE 7.—*Spraying schedule for the control of brown-rot on prunes and sweet cherries in western Washington and Oregon.*

Application and time.	For use on prunes.	For use on sweet cherries.
First brown-rot spray (bud spray): Apply when blossom buds are white and before full bloom (Pl. III, fig. 1).	**Bordeaux mixture 4–4–50.** **Lime-sulphur 1 to 50.** Self-boiled lime-sulphur 8–8–50. Sulphur dust.	**Bordeaux mixture 4–4–50.** **Lime-sulphur 1 to 50.** Sulphur dust.
Second brown-rot spray (calyx spray): Apply as soon as most petals have fallen.	**Bordeaux mixture 4–4–50.** **Lime-sulphur 1 to 50.** Self-boiled lime-sulphur 8–8–50. Sulphur dust.	**Bordeaux mixture 4–4–50.** **Lime-sulphur 1 to 50.** Sulphur dust.
Third brown-rot spray: Apply as soon as the husks are shed.	**Self-boiled lime-sulphur 8–8–50.** Bordeaux mixture 4–4–50. Sulphur dust.	Lime-sulphur 1 to 50. Sulphur dust.
Fourth brown-rot spray: Apply two to three weeks before fruit is ripe.	**Self-boiled lime-sulphur 8–8–50.** Bordeaux mixture 4–4–50. Sulphur dust.	Lime-sulphur 1 to 50. Sulphur dust.

The more important applications are printed in black-faced type, and the more effective and safest spray materials for use in each application are likewise indicated where any difference has been shown to exist. A spreader should be combined with the fungicide in each application, particularly the third and fourth. Casein spreaders may be used with any of the sprays above mentioned, but rosin-fishoil soap can not be used with lime-sulphur.

This entire schedule is required for complete insurance against brown-rot, and it may occasionally be necessary to put on an emergency application in case of unusually damp and rainy weather.

SUMMARY.

This bulletin reports the results of five-years' investigation of brown-rot of prunes and sweet cherries as it occurs in the lower Columbia and Willamette Valleys.

No evidence was found that the disease was carried over the winter by twig cankers or by mummies remaining on the tree.

Apothecia were abundant in the uncultivated prune orchards, arising in most cases from prunes that were but partly buried or that were in the first 2 or 3 inches of soil, but sometimes traced to prunes that were buried to a depth of 5 inches.

Apothecia were found on Black Republican cherries. This appears to be the first instance in which the apothecial stage has been reported on cherries.

Blossom infection always occurred on both prunes and cherries, sometimes destroying a third to a half of the young prunes and even a higher percentage of the cherries. Applications of spray just before the blossoms opened and just after the petals had fallen decreased the blossom infection. The losses from blossom infection sometimes resulted in a decreased crop, but in other cases the set of fruit on the sprayed and unsprayed trees was evened up by later "drops."

Lime-sulphur frequently caused severe spray injury on prunes, and Bordeaux mixture also sometimes caused injury. Both Bordeaux mixture and self-boiled lime-sulphur resulted in smaller sized sweet cherries.

It was found necessary to add calcium caseinate or rosin-fishoil soap to the spray materials in order to secure satisfactory spreading and sticking qualities on the fruit.

During the period of the experiments there was never a serious epidemic of brown-rot in the orchards in which the tests were made, but the disease often caused heavy losses in neighboring unsprayed orchards. All the various standard spray materials were found fairly efficient in holding the disease in check. An application of spray three to five weeks before picking time was found particularly valuable.

Holding and shipping tests showed that orchard spraying may be of great value in improving the keeping quality of fruit even when the amount of disease in the orchard is practically negligible.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE.

January 16, 1924.

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